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Health status of preweaned dairy heifers in the United States

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Abstract

The first national estimates of mortality and morbidity for preweaned dairy heifers in the US were generated from monitoring heifers from 906 operations in 28 states prospectively using a daily diary card system. Results indicated that the cumulative mortality incidence risk from birth to 8 weeks of life was 6.3% with a peak of 1.9% during the first week of life. Season of birth was significantly associated with cumulative mortality incidence risk, and mortality risk was highest in the periods January to March and October to December. Cumulative incidence risk of diarrhea to 8 weeks of age was 24.6% with a peak of 15.4% during the second week of life. Diarrhea incidence risk varied by region, with the West having the highest incidence risk (30.5%) and the Northeast the lowest (19.2%), as well as by herd size, with the smallest herd size having the lowest reported incidence risk of diarrhea to 8 weeks of age (18.8%). Other reported 8 week cumulative disease incidence risks included listlessness, 10.0%; respiratory disease, 8.4%; dehydration, 4.1%; lameness or joint problems, 1.1%.

Keywords: Dairy heifer ; Mortality ; Morbidity

1. Introduction

Replacement heifers represent the milk production potential of a dairy herd. The goal of dairy-heifer rearing is to raise healthy heifers that will freshen at the desired time and produce a profitable quantity of high-quality milk. One measure of the quality of heifer rearing management is an assessment of heifer health. Heifer health is important because, beyond economic losses associated with calf mortality, calfhood morbidity is

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also associated with survival and reproduction later in life (Correa et al., 1988, Curtis et al., 1989).

A few estimates of calfhood mortality and morbidity from prospective data recording with the specific purpose to evaluate dairy heifer health have been previously reported from specific geographic locations. These reports, from Ontario (Waltner-Toews et al., 1986a), New York (Curtis et al., 1988), the Netherlands (Perez et al., 1990), and Ohio (Lance et al., 1992), have been regional in focus and therefore have not encompassed the wide variety of management practices used across the US. Variation of results indicated in these reports demonstrates the difficulty in generalizing to the national US population of dairy heifers. This lack of baseline national information was noted in a 1989 report from a group of dairy specialists (USDA-APHIS-VS, 1989a) and was later detailed by a national group of dairy heifer specialists (USDA-APHIS-VS, 1989b) as the needed focus of a national study.

As a result, a national study of dairy heifers, the National Dairy Heifer Evaluation Project (NDHEP) was conducted by the U.S. Department of Agriculture-Animal and Plant Health Inspection Service-Veterinary Services in 1991 and 1992 as part of the National Animal Health Monitoring System. Some results from this study have been published (USDA-APHIS-VS, 1993, 1994, Heinrichs et al., 1994). The primary breed for 95% of the operations represented in the NDHEP study was Holstein and the reported rolling herd average milk production was 7592 kg. The annual dairy calf crop, defined as dairy calves born alive or moved onto the operation during the previous 12 months, was estimated to be 91.4% of the number of dairy cows and heifers of breeding age or older on the operation. The reported herd average age at heifer weaning was 7.9 weeks. From first phase NDHEP data collected retrospectively, the preweaned dairy heifer, with 8.4% mortality (ratio of preweaned heifer calf deaths to heifer calves born alive or moved onto the operation), was identified as a high risk age group, compared to heifers from weaning to first calving (which had 2.2% mortality). Further, 52% of deaths for preweaned heifers were attributed by producers to diarrhea and 21% to respiratory problems. These results compare to 18% of postweaned heifer deaths attributed to diarrhea and 35% to respiratory problems.

The objective of the NDHEP reported here was to prospectively assess the health of preweaned dairy heifers on US dairy operations and evaluate differences by region, herd size, and season. This study included prospective assessments of weekly mortality and disease incidence (diarrhea, respiratory disease, listlessness, dehydration and lameness) in preweaned dairy heifers.

2. Materials and methods

The NDHEP was designed to measure baseline calfhood management practices and replacement heifer calf health status for the US dairy heifer population in 1991 and 1992 (Heinrichs et al., 1994). A stratified random sample of dairy herds was selected from USDA-National Agricultural Statistics Service (NASS) list and area frames in 28 states. Approximately 83% of the US dairy cow population was located in these 28 states. Using January 1, 1991 Cattle Survey data from NASS, herds eligible for inclusion were

dairy herds with at least 30 dairy cows and heifer ranches (defined as operations with more than 50 calves weighing less than 227 kg, no dairy or beef cows, and no heifers or steers weighing more than 227 kg).

In the first phase of the study (Heinrichs et al., 1994), NASS enumerators visited and collected responses from 1811 voluntarily participating dairy producers (Table 1). One quarter of the herds was visited in each of the following months: March 1991, June 1991, September 1991, and December 1991. In the second phase, federal or state veterinary medical officers or animal health technicians recorded information relating to the management of 1177 respondent operations via questionnaires administered from 1–3 months following the NASS visit (USDA-APHIS-VS, 1993). During this study phase, each dairy-calf producer also recorded calf health events (from birth to weaning) for up to 40 liveborn replacement heifers over a 3 month period using a calving log and daily diary card system with standardized data forms. Health events reported prospectively by the calf producers included death; diarrhea or scours; cough, runny nose or eyes, or difficult breathing; listlessness, droopy ears, dullness, or off feed; dehydrated, sunken eyes; lameness or joint problems; and other. Information related to the "other" category was not included in this report. To maintain the highest quality data, each producer was instructed by the visiting federal or state veterinary medical officer about data-recording procedures. These veterinary medical officers received training prior to the study to seek high-quality data from producers and visited each participant operation on at least three separate occasions to review records, collect data, and respond to data-recording inquiries.

Producer-recorded data quality was assessed by the federal or state veterinary medical officer visiting the operation, using a five-point score (Appendix). In addition, the USDA-APHIS NAHMS coordinator in each state reviewed the data and scored each operation based on errors and completeness. Validation also included computerized range check and logistical consistency procedures performed at the time of computerized data entry by the NAHMS coordinator in each state. Flagged records were edited with producer callbacks if necessary. Review of raw and edited data was performed by

Table 1
Response by dairy operations to the National Dairy Heifer Evaluation Project

Response level	Number of dairy operations
Herds contacted for first phase survey by USDA-NASS	3346
Herds eligible for first phase survey by NASS (at least 30 milk cows or heifer ranch)	3204
Respondent herds to first phase survey by NASS	1984 (62% of 3204)
Respondent herds to first phase survey by NASS with dairy calves expected to be born within 3 months	1811
Herds that agreed to APHIS visit	1726
Respondent herds to second phase survey by APHIS	1177 (65% of 1811)
Respondent herds to prospective monitoring of preweaned heifer health	1040
Herds that completed prospective monitoring of preweaned heifer health with quality records	906 (77% of 1177)

USDA-Veterinary Services personnel at a later stage to identify and remove from analyses those operations with poor data quality.

Validated data from the 906 respondent operations with quality data were weighted to represent the population sampled: dairy herds of more than 30 milking cows and heifer ranches of more than 50 heifer calves in the 28 sampled states. These operations represented 78% of the national dairy cow population. The weighting methods used were similar to those described previously for large complex surveys (Dargatz and Hill, 1996). Herd-level analysis weights were based upon the sampling fraction of herds and adjusted for nonresponse at each phase of the study. Adjustments for nonresponse were made by region, herd size, and season, and for each region–herd size–season stratum was equal to the sum of weights for the eligible operations divided by the sum of weights of the respondents. Calf-level analysis weights were computed as the herd-level analysis weight multiplied by the calf-level adjustment. The calf-level adjustment equalled the total number of eligible heifer calves on the operation divided by the number of heifer calves monitored.

The population of heifer calves monitored was dynamic throughout the study period. Calves entered the monitoring phase at the start of the study or when born alive. Calves left the study when they were weaned, removed from the herd, died, lost identification, or when the study ended for that operation. Estimates of mortality and morbidity for the dairy heifers were generated using specialized software for survey data analysis (SUDAAN User's Manual, 1990) using life-table analyses (Lee, 1992). Calves were grouped by week of life into eight weekly cohorts (week 1 equalled 0 to 6 days of life, week 2 equalled 7 to 13 days of life, etc.) For estimates of mortality and morbidity, weekly cohorts of heifer calves were defined as heifers present at the beginning of the week and the end of the week or heifers present at the beginning of the week that died during the week. Week 1 mortality incidence risk (estimated as risk per week) was calculated by dividing the weighted number of cohort heifers dying within week 1 by the total weighted number of heifers in the week 1 cohort. For week 2, the cumulative mortality incidence risk was calculated by multiplying the percentage of week 1 cohort calves that survived week 1 by the percentage of week 2 cohort calves that survived week 2 and subtracting this total from 1. Similar calculations were performed for weeks 3 through 8. For morbidity, the incidence risk of calves with reported signs of disease was calculated similarly to that for weekly mortality incidence risk. Cumulative incidence risk of each disease was estimated only for those calves monitored from birth, using the first reported event of each disease type (e.g., diarrhea) for each calf, using a similar methodology as that for cumulative mortality risk.

For statistical comparisons between regions, herd sizes, and seasons of birth, univariable Cox proportional hazards regression analyses were performed using survey data analysis software (SUDAAN User's Manual, 1990). In these analyses, the statistical software adjusted for the stratification and herd clustering of the study design, as explicitly specified, in the estimation of variance. P values were based on the Satterthwaite adjusted F statistic. The Cox regression assumption of proportional hazards (that the hazard rate of a calf with a specific factor is a constant multiple of the baseline hazard at all times) was tested using graphical methods (PROC LIFETEST; SAS User's Guide, 1990). The response variable was defined as the age of death or

censoring for mortality analyses, or the age of first onset of specific disease or censoring for morbidity analyses. For both mortality and morbidity analyses, calves evaluated were those monitored from birth. Relative risks and 95% confidence limits were computed from exponentiation of the Cox-model beta coefficients. Herds were stratified by region [1], herd size [2], and season of calf birth [3] for comparison purposes.

3. Results

There were 12228 preweaned dairy heifer calves included in the statistical comparisons of region, herd size, and season of birth. For weekly mortality cohorts, the unweighted number of calves within each weekly cohort was 11674 in week 1, 11550 in week 2, 11243 in week 3, 10921 in week 4, 10310 in week 5, 9436 in week 6, 8150 in week 7, and 7073 in week 8. For weekly morbidity cohorts, the unweighted number of calves within each weekly cohort was 11674 in week 1, 10794 in week 2, 9933 in week 3, 9074 in week 4, 8044 in week 5, 6861 in week 6, 6047 in week 7, and 4299 in week 8. Graphical methods used to evaluate the proportional-hazards assumption indicated that the assumption was reasonable for these data.

Ninety-five percent of the dairy operations included in the final analyses received a data quality score of 1, 2, or 3 from the visiting veterinary medical officer or animal health technician, indicating excellent, good, or average data quality. Related to data error frequency and completeness, 95% of the dairy operations included in the final analyses were scored as 1, 2, or 3 by the USDA-APHIS NAHMS Coordinator reviewing records in the states, indicating excellent, good, or average data quality at this level.

From unweighted nonresponse distributions (Table 2), response rate was not associated with mortality of liveborn preweaned heifers. Respondents and nonrespondents at this phase of the study were compared using data collected retrospectively in the first phase of the NDHEP (retrospective estimate of 8.4% overall mortality, USDA-APHIS-VS, 1994). Variables associated with response were region, % of cows registered, rolling herd average milk production, and highest education level of operator. Although the differences in response rates by these variables was significant statistically, the magnitudes of these differences were generally small. The greatest difference was noted in highest education level, with response rates varying from 36% for grade school to 63% for college graduates. From further analyses, region was associated with percent of cows registered, rolling herd average milk production, and education level of operator ($P < 0.001$ for each from chi-square analyses) and from Spearman correlation analyses,

[1] Regions included: West - California, Oregon, Washington, Idaho, Colorado, Midwest-Minnesota, Nebraska, Iowa, Wisconsin, Illinois, Indiana, Ohio, Michigan; Northeast - Pennsylvania, New York, Vermont, New Hampshire, Maine, Massachusetts, Connecticut, Rhode Island; Southeast - Maryland, Virginia, North Carolina, Tennessee, Georgia, Alabama, Florida.

[2] Herd sizes included: 5 or less preweaned dairy heifers on the operation at the time of the first herd visit, 6–15 preweaned dairy heifers, and 16 or more preweaned dairy heifers.

[3] Seasons were evaluated using the month of birth for each calf monitored and included: January through March, April through June, July through September, October through December.

Table 2
Comparison of percent response to prospective monitoring of liveborn US dairy heifer calves by variable, with data from first phase of NDHEP study (unweighted univariable analyses)

Variable and level	Herds				
	Total number	Number of respondents	Response as % of total	*RR* [1]	95% CL [2]
Region					
West	373	173	46	1.0	–
Midwest	693	341	49	1.06	0.94, 1.19
Northeast	414	234	56	1.23	1.07, 1.42
Southeast	331	158	48	1.03	0.89, 1.18
Herd size					
≤ 5 preweaned heifers	633	306	48	1.0	–
6–15 preweaned heifers	641	326	51	1.05	0.94, 1.17
> 15 preweaned heifers	537	274	51	1.06	0.94, 1.18
Quarter of study					
1	560	269	48	1.00	0.87, 1.15
2	386	199	52	1.08	0.93, 1.24
3	357	171	48	1.0	–
4	508	267	52	1.10	0.96, 1.26
Average weaning age					
≤ 7 weeks	656	338	52	1.01	0.90, 1.13
7.1–8 weeks	553	293	53	1.04	0.92, 1.16
> 8 weeks	506	259	51	1.0	–
% of cows registered					
0%	988	444	45	1.0	–
0.1–25%	414	223	54	1.19	1.06, 1.34
> 25%	396	239	60	1.39	1.23, 1.57
Rolling herd average milk production					
≤ 7273 kg	616	294	48	1.0	–
7273–8409 kg	618	302	49	1.02	0.92, 1.14
> 8409 kg	552	309	56	1.19	1.05, 1.34
Ratio of preweaned heifers died to heifers born alive					
0	764	410	54	1.09	0.98, 1.22
0.01–0.1	447	232	52	1.06	0.93, 1.20
> 0.1	474	233	49	1.0	–
Highest education level of operator					
Grade school	177	64	36	1.0	–
High school	955	453	47	1.22	1.06, 1.39
Some college/tech school	392	211	54	1.38	1.18, 1.63
B.A./B.S./grad school	281	178	63	1.74	1.44, 2.11
Day-to-day decisionmaker					
OOne person	1171	564	48	1.0	–
Partners	588	48	54	1.12	1.02, 1.24
Hired manager	48	25	52	1.08	0.81, 1.44

[1] Stratum-specific relative risks and 95% test-based confidence limits from univariable analyses.
[2] CL = Confidence limit.

Table 3
Weekly incidence risks of selected health events of liveborn US preweaned dairy heifers by week of age (weighted)

Week of age	Mortality		Diarrhea		Respiratory	
	Incidence (%)	95% CL [1]	Incidence (%)	95% CL	Incidence (%)	95% CL
1	1.9	1.4, 2.4	8.2	6.9, 9.4	2.4	1.5, 3.3
2	1.5	1.1, 1.9	15.4	12.8, 17.9	2.9	1.9, 3.9
3	1.1	0.7, 1.4	7.1	5.6, 8.5	1.5	0.9, 2.1
4	0.5	0.2, 0.8	2.9	2.2, 3.5	1.2	0.8, 1.7
5	0.5	0.3, 0.8	2.0	1.4, 2.6	1.6	0.9, 2.3
6	0.3	0.1, 0.4	1.0	0.5, 1.4	1.8	1.0, 2.5
7	0.4	0.1, 0.6	0.6	0.4, 0.9	1.5	0.9, 2.0
8	0.4	0.0, 0.8	0.7	0.3, 1.0	1.8	0.9, 2.6
	Listlessness		Dehydration		Lameness	
1	3.5	2.5, 4.5	1.3	0.9, 1.6	0.2	0.1, 0.4
2	3.8	2.8, 4.7	2.0	1.5, 2.4	0.5	0.2, 0.9
3	1.9	1.3, 2.4	1.0	0.6, 1.3	0.4	0.0, 0.7
4	1.5	0.9, 2.0	0.3	0.1, 0.4	0.2	0.0, 0.4
5	1.5	0.8, 2.1	0.3	0.1, 0.4	0.1	0.0, 0.2
6	1.0	0.5, 1.4	0.2	0.1, 0.3	0.1	0.0, 0.2
7	0.9	0.5, 1.3	0.1	0.0, 0.3	0.1	0.0, 0.3
8	0.9	0.4, 1.4	0.1	0.0, 0.2	0.0	0.0, 0.0

[1] CL = Confidence limit.

herd size was correlated with % of cows registered ($P = 0.02$) and rolling herd average milk production ($P = 0.0001$). Region, herd size, and season were used as weight adjustment strata to account for nonresponse to prospective monitoring.

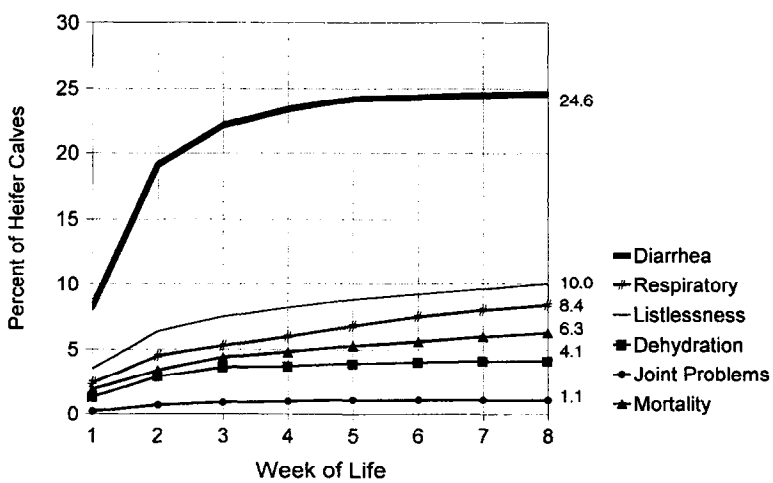

Fig. 1. Cumulative incidence risks of mortality and morbidity of liveborn US dairy heifer calves to 8 weeks of age, 1991–92.

Table 4
Associations between mortality, diarrhea and respiratory disease incidence risk of liveborn US dairy heifers to 8 weeks of age and region, herd size, and season of birth

Outcome, variable, strata	Cox regression (univariable analyses)		
	P-value [1]	*RR*	95% CL [2]
Mortality			
Region	0.5		
Herd size	0.5		
Season	0.05		
January–March		1.01	0.74, 1.37
April–June		0.59	0.39, 0.90
July–September		0.71	0.50, 1.02
October–December		1.0	–
Diarrhea			
Region	0.01		
West		1.40	1.09, 1.80
Midwest		1.0	–
Northeast		0.77	0.59, 1.0
Southeast		1.01	0.83, 1.24
Herd size (preweaned heifer inventory)	0.001		
≤ 5		1.0	–
6–15		1.50	1.26, 1.77
> 15		1.62	1.32, 1.99
Season	0.1		
Respiratory disease			
Region	0.05		
West		1.14	0.71, 1.82
Midwest		1.0	–
Northeast		0.63	0.49, 0.82
Southeast		0.49	0.29, 0.83
Herd size (preweaned heifer inventory)	0.001		
≤ 5		1.0	–
6–15		2.20	1.71, 2.83
> 15		2.21	1.58, 3.10
Season	0.6		

[1] *P* values from Satterthwaite adjusted *F* statistics from univariable Cox regression analyses, with relative risk (*RR*) and 95% upper and lower confidence limits provided if $P \leq 0.05$.
[2] CL = Confidence limit.

Preweaned heifer mortality was highest during the first 3 weeks of life with the highest mortality incidence risk (1.9%) during the first week of life (Table 3). The cumulative mortality incidence risk from liveborn birth through 8 weeks of age was 6.3% (Fig. 1). Regional, herd size, and seasonal comparisons of preweaned mortality distributions indicated that mortality differed significantly by season of birth ($P = 0.05$, Table 4). The highest cumulative mortality risk (7.8%) occurred from January through March and October through December (Fig. 2). Numerical differences were noted in mortality incidence among regions and herd size but these were not statistically different.

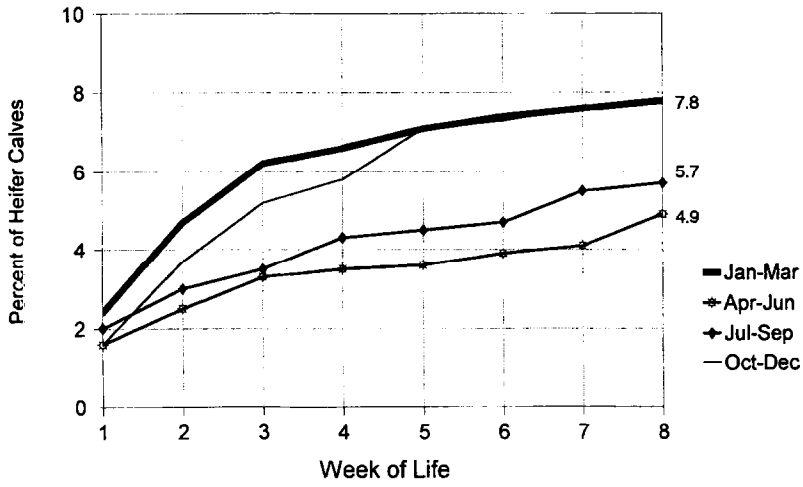

Fig. 2. Cumulative incidence risk of mortality of liveborn US dairy heifer calves to 8 weeks of age by season of birth, 1991–92.

Signs of disease identified by producers were most commonly observed during the first 2 weeks of calf life (Table 3). Diarrhea, the most-commonly recognized disease event, peaked at 15.4% during the second week of life. The second week of life was also the peak time for reported incidence risk of respiratory problems, listlessness, dehydration, and lameness. Estimates of cumulative preweaned morbidity risk are shown in Fig. 1, where 24.6% of calves were observed with diarrhea by 8 weeks of life (the national

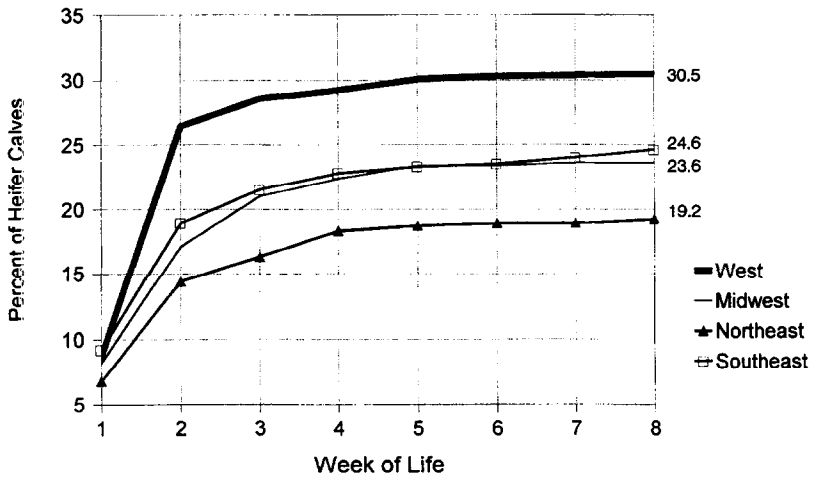

Fig. 3. Cumulative incidence risk of diarrhea of liveborn US dairy heifer calves to 8 weeks of age by region, 1991–92.

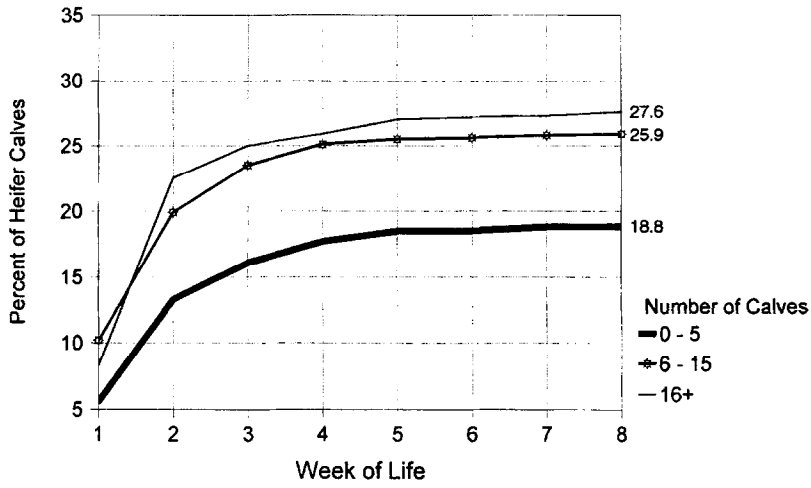

Fig. 4. Cumulative incidence risk of diarrhea of liveborn US dairy heifer calves to 8 weeks of age by herd size, 1991–92.

average age of weaning, USDA-APHIS-VS, 1993). Other cumulative incidence risks of disease to 8 weeks of life were listlessness, 10.0%; respiratory problems, 8.4%; dehydration, 4.1%; and lameness or joint problems, 1.1%.

Diarrhea incidence risk differed significantly by both region ($P = 0.01$, Table 4) and herd size ($P = 0.001$). The association with season of birth was marginal ($P = 0.1$). Dairy operations in the West (Fig. 3) reported the highest cumulative incidence risk of

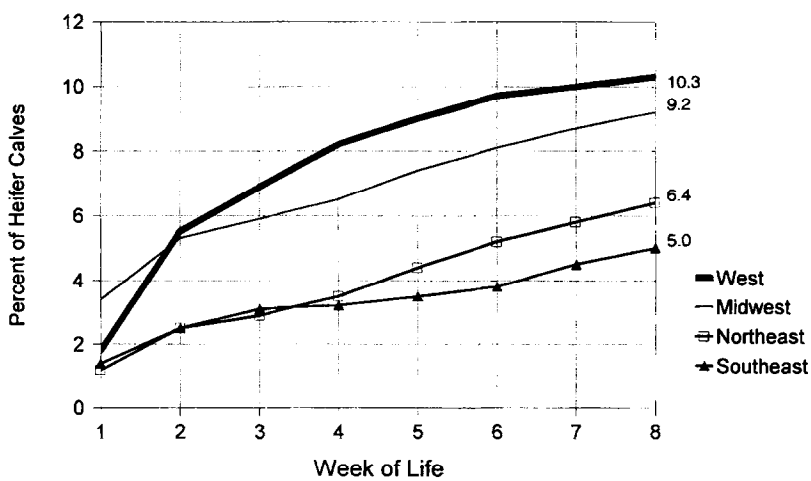

Fig. 5. Cumulative incidence risk of respiratory disease of liveborn US dairy heifer calves to 8 weeks of age by region, 1991–92.

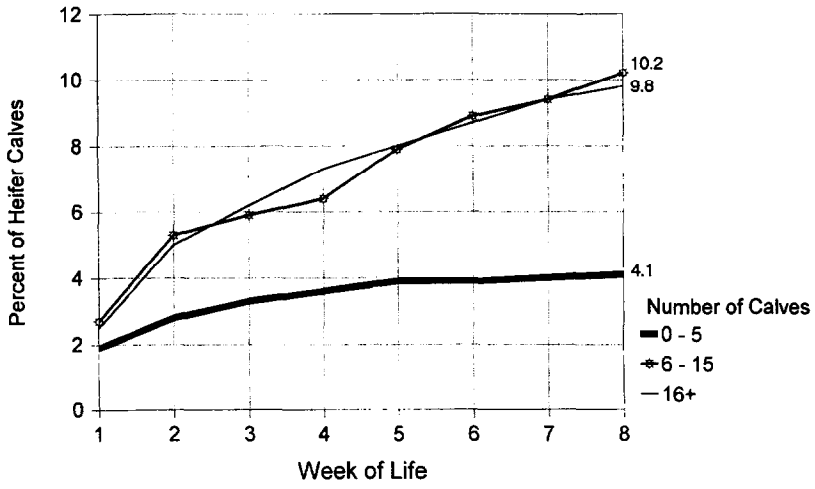

Fig. 6. Cumulative incidence risk of respiratory disease of liveborn US dairy heifer calves to 8 weeks of age by herd size, 1991–92.

diarrhea and those in the Northeast reported the lowest cumulative incidence of diarrhea. Among herd-size groups (Fig. 4), operations with the smallest herd size (five or less preweaned heifer calves at herd visit) reported the lowest cumulative incidence of diarrhea.

Reported incidence of respiratory disease differed by region ($P = 0.05$) and herd size ($P = 0.001$), but not season of birth (Table 4). Western and Midwestern dairy operations reported higher cumulative incidence risks of respiratory disease than those in the Northeast and Southeast (Fig. 5). In addition, (Fig. 6), the smallest herds (five or less preweaned heifer calves) reported the lowest cumulative incidence risk of respiratory problems (4.1%).

4. Discussion

This study was the first to estimate the national incidence risk of mortality and morbidity in US dairy heifers. It incorporated on-farm prospective data collected from a statistically-based sample of 906 respondent dairy operations across the US. Inherent in this magnitude of study were differing definitions of disease events by many calf producers with various calf management systems across the country. For this reason, disease reporting was limited to visible signs of disease (e.g., diarrhea) rather than specific clinical disease entities (e.g., rotaviral diarrhea), similar to methods previously used in observational studies (Curtis et al., 1988).

Weekly cohorts were used to estimate incidences of mortality and morbidity because of the dynamic nature of the preweaned dairy heifer population and for ease of interpretation. For statistical comparisons of region, herd size, and season, survival

analysis procedures (Cox proportional hazards regression) were used to account for censored observations (i.e., calves monitored for only part of the study) in the analyses. Another advantage of Cox regression using survey data analysis software (SUDAAN User's Manual, 1990) was the ability to account for within-herd clustering and sample design stratification unlike usual life table analyses, which assume simple random sampling. SUDAAN computes variances by first forming the Taylor series linearization for each statistic, which are then substituted into the formula for computing the variance appropriate for the design specified by the user (SUDAAN User's Manual, 1990).

Based upon the results from the producer and field data quality scores, the overall data quality was considered satisfactory for the estimates generated. The nonresponse adjustment used was standard for survey sampling (Dargatz and Hill, 1996) and provided a reasonable method for removing potential bias from nonresponse, considering the variables selected for adjustment (region, herd size, and season of calf birth) were plausibly related to response and were either related to response or associated with other variables related with response.

The estimate of 6.3% cumulative mortality incidence risk during the first 8 weeks of life was somewhat higher than those reported from prospective studies in the Netherlands (4.6% from birth to 8 weeks, Perez et al., 1990), New York (2.8% from 24 h of age to 8 weeks, Curtis et al., 1988), and Ontario (3.8% from birth to weaning, Waltner-Toews et al., 1986a). This estimate of 6.3% mortality incidence to 8 weeks of life did not include stillbirth mortality, which was estimated to be an additional 1.6% (SE = 0.4) of heifer calves born (USDA-APHIS-VS, 1994). Results from this study point out that mortality and morbidity incidence risk are highest during the first 2 weeks of life, a crucial period during the life of a dairy calf. Optimal management of calves in the first 2 weeks of life could potentially have high payoffs in reduction of disease and mortality.

Preweaned heifer mortality in the US was highest for calves born in winter and fall, and lowest for calves born in warmer spring and summer months. These results differ from previously reported results (Waltner-Toews et al., 1986b,Curtis et al., 1988, Perez et al., 1990), which did not identify seasonal mortality differences in New York, Dutch, and Ontario herds. One explanation for this difference is the different and broader geographic distribution of the heifers sampled in this national US study compared to the other more localized studies.

Previous studies (Waltner-Toews et al., 1986c,Lance et al., 1992) reported larger herds having the highest calfhood mortality incidence, but herd size differences were not observed in this study. One explanation is that this study differed from others in that herds with less than 30 cows were excluded from the population sampled. Another is the different and broader geographic distribution of heifers included in this study compared to the others.

The reported 24.6% cumulative incidence risk of diarrhea to 8 weeks of life compared well with 27% from the Dutch study from birth to 8 weeks (Perez et al., 1990) and the 20% estimate from birth to weaning from Ontario (Waltner-Toews et al., 1986a), although higher than the 15% estimate from 24 h of age to 8 weeks from New York (Curtis et al., 1988). The 2 week diarrhea cumulative incidence risk of 19.1% (14.4% in the Northeast U.S.) was similar to that from the Netherlands (Perez et al., 1990) but

higher than the 10.2% from New York (Curtis et al., 1988) during the first 2 weeks of life. The reported 8.4% cumulative incidence risk of respiratory signs within the first 8 weeks of life was higher than that reported from New York (6.1% from 24 h of age to 8 weeks; Curtis et al., 1988) and the Netherlands (5.0% from birth to 8 weeks; Perez et al., 1990). It was lower than that reported from Ontario (15%; Waltner-Toews et al., 1986a), but that estimate included calves beyond 8 weeks of age until weaning. The West had the highest cumulative reported incidence of both diarrhea and respiratory disease.

The lowest cumulative incidence risk of diarrhea and respiratory disease was reported in the smallest-sized herds. This result could be an indication that calves on smaller dairy operations are at lowest risk for diarrhea and respiratory disease, perhaps partially related to less intensive calf rearing. However, the cumulative mortality incidence risk was not lower for the smallest sized herds, indicating that this lower risk of diarrheal and respiratory diseases did not lead to lower risk of death in these calves. Further analyses have been reported in an accompanying paper to more fully characterize relationships between mortality and specific risk factors.

5. Conclusions

Results from the first statistically based national study of dairy heifer health in the US indicated that the highest mortality and morbidity incidence occurred during the first 2 weeks of life – an indication that heifer management should be focused toward the neonatal heifer. These results also provide baseline national and regional estimates of mortality and morbidity for future comparisons by dairy producers, veterinarians, and dairy consultants.

Appendix A

A.1. Producer and field data quality scores.

A.1.1. Producer data quality score

Score	Classification	Definition
1	Excellent	Producer has no problem responding to the questionnaire either through knowledge of the operation or by consulting available records. There is no question about the validity of the data this producer provided.
2	Good	Producer has few problems in responding to most data items and must search records for problem areas. There is little question about the data quality this producer provided.
3	Average	Producer is knowledgeable about the operation but has some difficulty with specific questions. Records are consulted for some questions.

4	Minimally acceptable	Producer is not very knowledgeable about some aspects of the operation asked on the questionnaire. Data for these sections are based on the producer's best and earnest recollection and knowledge. Records were not consulted.
5	Not acceptable	Data values and relationships do not fit together at all. Producer exhibits disregard for valid data and most data are based on wild guesses.

A.1.2. Field data quality score

Score	Classification	Definition
1	Excellent	No errors. Questionnaire is legible and easy to edit. Comments are present to explain unusual situations. A good effort was made.
2	Good	No major errors are detected. Comments are adequate to explain most situations. Editing the questionnaire is not difficult.
3	Average	May have a few errors, but questionnaire can be edited to reasonableness. Completion of questionnaire is adequate, but shows some need for improvement.
4	Minimally acceptable	Questionnaire was completed, but has several errors that makes editing difficult. Comments explaining unusual situations are not present. Follow-up with the veterinary medical officer is needed before questionnaire can be completed.
5	Not acceptable	Questionnaire is completed, but has many errors. Comments are not present or inadequate. Follow-up with the veterinary medical officer or respondent may be needed before questionnaire can be edited.

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